Mat. Res. Soc. Symp. Proc. Vol. 674 © 2001 Materials Research Society

Analysis of Multipulse Strategies for High Data Rate Phase Change Optical Recording

Aparna C. Sheila, T.E. Schlesinger,
DSSC, ECE Department, Carnegie Mellon University
Pittsburgh, PA 15213, U.S.A

ABSTRACT

Multipulse strategies for two disk rotation velocities of the same phase change optical disk, were analyzed using simulations, at red and blue wavelengths. Results showed that at either wavelength, lower pulse duty cycles are needed at lower velocities to reduce recrystallization and higher duty cycles are needed at higher velocities. Optimal erase powers and cooling width for minimal overwrite jitter were also found.

INTRODUCTION

To achieve higher data rates in phase change (PC) optical recording, there are two options: one is to write smaller bits by decreasing the laser wavelength and/ or increasing the numerical aperture (NA) of the objective lens while the other option is to increase the disk rotation velocity for a given wavelength and NA. Using higher linear velocities is advantageous from the reliability and removability of the disk perspective, since the distance between the PC media and the lens has to be decreased when a high NA lens is used. In this paper, we look at some issues in achieving high data rates by increasing the disk rotation velocity. The maximum data rate achievable in a phase change recording material is limited by the time taken to crystallize or erase an amorphous mark. When constant angular velocity mode is used, different locations on the PC disk will be subjected to different linear velocities. The maximum velocities that give reasonable erasability depends on wavelength. We consider two velocities each, at red (640nm) and blue (430nm) wavelength and investigate how the multipulse parameters such as the pulse duty cycle, erase power and cooling width should be modified to give comparable performance at the two velocities.

SIMULATION

The time spent by any point on the disk under laser irradiation is referred to as the effective heating duration [1] $t_h = d/v$, where d is the laser spot diameter and v is the linear velocity. GeSbTe (GST) alloys crystallize through nucleation followed by grain growth. The minimum time for crystallization is therefore limited by nucleation time. It was shown that using the GST alloys, velocities upto 50m/s, with an effective heating duration of 17.5 ns would give reasonable erasability of 30 dB [1]. We assume that with crystallization enhancement layers on either side of the phase change layer, t_h can be 15ns. This gives for red (640nm) and 0.85 NA, a maximum velocity of 50m/s and for blue (430nm) with 0.85 NA, 33.5m/s.

We numerically solved the thermal diffusion equation and the crystallization kinetics of nucleation and growth alternately in each time interval, taking into account the phase changes that occur. The time interval between nucleation events was modeled as a random variable with an exponential density function. We assume two-dimensional nucleation and growth. The details of the simulation are given in Ref.2. The intensity of a read back beam was convolved with the reflectivity of the disk to generate read back signals. We consider 10m/s and 50m/s at 640nm and 10m/s and 30m/s at 430nm.

While overwriting, the difference in absorption between the two phases results in different sized marks depending on the previous state of the medium. To compensate for this, absorption controlled disks [4] were designed and are shown in Fig.1. A Si layer is added for absorption control at 640nm and at 430nm, a tri layer dielectric structure is used. Thin layers of SiC and SiN are used in the red and blue respectively for promoting crystallization. Our model assumes homogenous nucleation, but to take into account the heterogeneous nucleation from the interfaces, we use a lower value of activation energy.

RESULTS AND DISCUSSION

Fig.1 shows a typical multipulse that is used in the simulations. The effect of pulse duty cycle on the signal modulation is shown in Fig.2. Duty cycle is the ratio of the pulse width (time spent in write power level, P_{wr}, within T (Fig.1)), to the pulse period, T. By modulation, we mean the difference between the maximum and minimum of the read back signal. At 10m/s, both at 640nm and at 430nm, we see that the signal modulation level first increases with duty cycle, reaches saturation and then starts decreasing. At the higher velocity of 50m/s and 30m/s for the red and blue respectively, it may be seen that at high duty cycles, the modulation level increases. This may be explained as follows. When the pulse duty is increased, there are two mutually opposing effects: one is the increase in mark size due to the larger molten area, and the second is the increase in recrystallization due to a decrease in cooling rate. If the extent of recrystallization overcomes the increase in mark size due to increase in pulse duty, the modulation will decrease compared to the value at lower duty cycles. This is what happens at the lower velocity since there is more time for recrystallization than at the higher velocity (see fig.3). At the higher velocity, the increase in mark size overcomes the recrystallization effect and so the modulation increases. However, the mark also tends to become tear drop shaped at high duty cycles and this is undesirable.

Al Alloy (200nm)
Si (20nm)
ZnS-SiO_2 (30nm)
SiC(5nm)
GST(10nm)
SiC(5nm)
ZnS-SiO_2 (50nm)
Substrate

Al Alloy (200nm)
ZnS-SiO_2 (25nm)
SiN(5nm)
GST(10nm)
SiN(5nm)
ZnS-SiO_2 (42nm)
SiO_2(50nm)
ZnS-SiO_2 (40nm)
Substrate

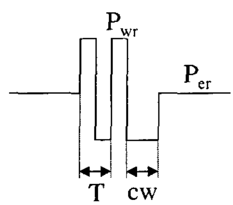


Fig.1. Disk structures used for the red wavelength (left) and for the blue wavelength. Also shown is the multipulse waveform for a 3T pulse (nT pulse has (n-1) pulses)

The minimum duty cycle that gives close to saturation modulation was chosen as the optimal duty cycle. At 10m/s, we chose 20% duty in the red and 25% duty in the blue. At 50m/s, red and at 30m/s, blue, 40% duty is chosen. At the higher velocity, the duty cycle is higher, as expected, to give the same performance

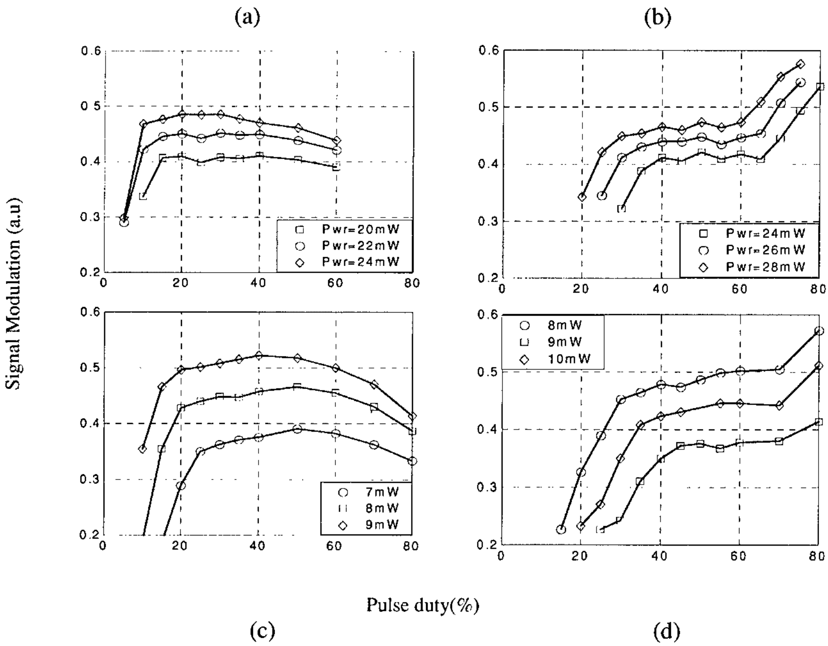


Fig.2. Plots of modulation as a function of the pulse duty cycle. 2.a and 2.b are for red wavelength and 2.c and 2.d are for the blue wavelength. 2.a and 2.c are at 10m/s linear velocity while 2.b and 2.d are at 50m/s for red and 30m/s for blue respectively.

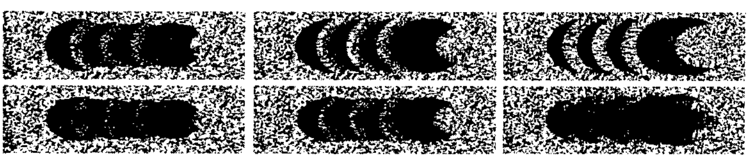


Fig.3. Images of simulated 5T marks at red wavelength. Top (L-R) 20%, 40% and 70% duty, all at 10m/s and bottom (L-R) 40%, 60% and 70% duty at 50m/s.

Fig.4 shows modulation as a function of write power using the optimal duty cycles. The modulation increases with write power and saturates. It may be noted that the power required in the blue is much less due to the smaller spot sizes and higher power densities. Also, the maximum modulation obtained with the blue is higher than red. This is due to the absence of the Si layer in the blue disk which makes it a more rapidly cooling disk as compared to the red disk, resulting in less recrystallization upon writing a mark.

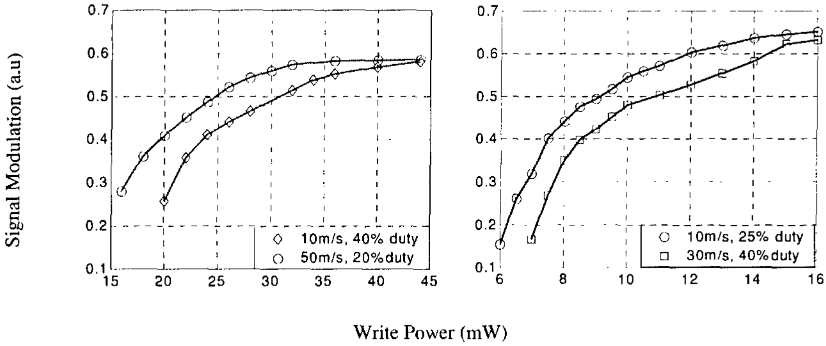


Fig.4. Signal modulation as a function of write power at red (left) and blue wavelength

Overwrite jitter is a major concern at high velocities and arises from the difference in absorption between the two phases. At low velocities, as the laser beam moves forward, it crystallizes areas ahead of it, so regardless of the previous state, the new mark is always written on a crystalline area. At high velocities however, there is insufficient time for this crystallization and so the new mark sizes depend on the previous state and overwrite jitter increases. We simulated overwrite jitter as follows. A 6T mark was first written and a 3T mark was overwritten on the 6T mark at different delays. The full width at half maximum (FWHM) of the 3T mark varies depending upon where it is overwritten. The standard deviation of FWHM gives the overwrite jitter.

First the effect of the erase power on overwrite jitter was simulated. The plots are shown in Fig.5. There is an optimal value of the erase power at which the overwrite jitter is minimum. At low erase powers, there is insufficient erasure of the old marks as may be seen from Fig.6a. This gives rise to high values of jitter. At high erase powers, the temperature goes above the melting point at the erase locations and this again leads to high jitter (Fig.6c). It may be seen from Fig.5, that the jitter at the blue wavelength is lower than that at the red and this we think is due to the fact that the disk structure for blue is of the rapid cooling type. Also, the range of usable erase power is narrower compared to red.

Another important parameter that controls overwrite jitter is the cooling width (*cw*, see Fig.1). Cooling width is the time duration immediately following the last write pulse in the multipulse, during which power is maintained at a low bias level. Cooling width controls the extent of recrystallization at the trailing edge and is therefore is one of the critical parameters to take care of, to minimize jitter. The effect of *cw* on jitter was investigated for the two wavelengths and is plotted in Fig.7. In DVD's *cw* is usually taken to be 1T, however, we find that at the higher velocities used here, the cooling width has to be much lower for minimum jitter. At 10m/s, for instance, the minimum is at 0.35T for blue and 0.4T for red and at the higher velocity, the value reduces further to 0.1T for blue and 0.3T for red. At *cw* values lower than optimal, there is insufficient time for cooling and the molten area spreads leading to higher jitter (see Fig.8c). At higher cooling widths, the previous mark will be incompletely erased since the erase power following the write power is farther away (Fig.8a). The effect at high *cw* is much more pronounced at the blue than at the red. This is due to the faster heat diffusion which gives less chance for return erase in the blue disk compared to the red, thereby resulting in high jitter. The same effect can again be seen at the higher velocity.

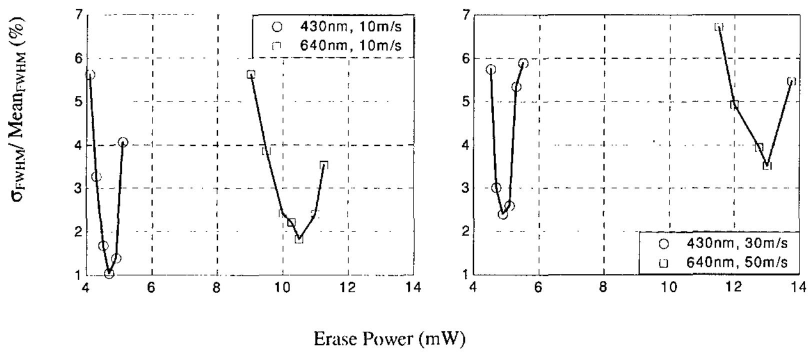
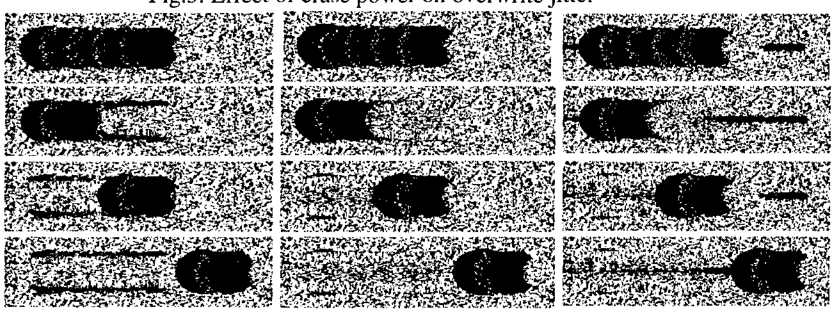


Fig.5. Effect of erase power on overwrite jitter



(a) (b) (c)

Fig. 6. Images showing the effect of erase power on overwrite. These are images at red wavelength at 50m/s. (a), (b) and (c) are at P_{er} of 11.5mW, 12.75mW and 13.25mW. Top row shows 6T marks and the next three rows are 3T marks written at delays of 0T, 2T and 6T (T-B). Each frame is 2.6μm x 0.8μm.

CONCLUSIONS

In this paper, we showed how some of the multipulse parameters should be varied at two different velocities for the same disk, to give comparable performance. The study was done at both red and the blue wavelength. The maximum velocity achievable at the two wavelengths differ due to the difference in the laser spot size. It was seen at either wavelength, the pulse duty cycle should be lower at lower velocity (20% and 25% duty at

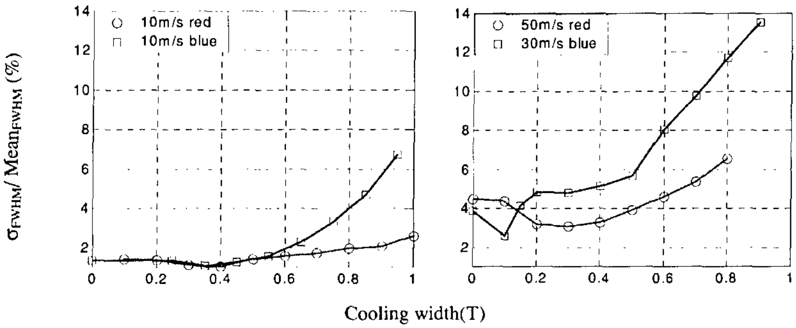
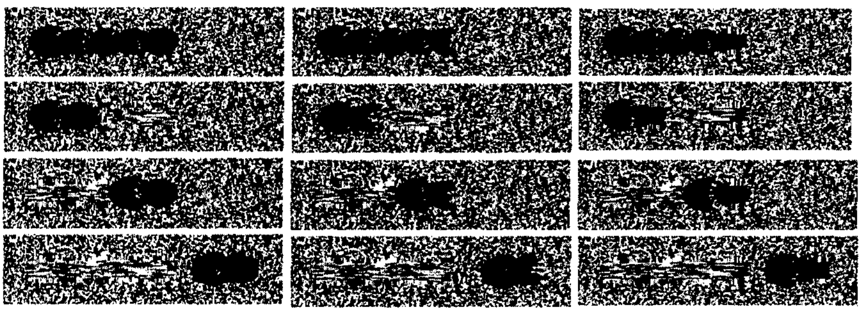


Fig.7. Effect of cooling width on overwrite jitter



(a) (b) (c)

Fig.8. Images of marks written with blue laser at 30m/s showing effect of cooling width on overwrite. (a), (b) and (c) are at cooling widths of 0.85T, 0.1T and 0.0T. Frame size and delays are same as Fig.6.

10m/s in red and blue) and higher (40%) at higher velocities (30m/s, blue and 50m/s, red) to give maximum signal modulation. To reduce overwrite jitter, cooling width is seen to be a critical factor and the cooling widths required at higher velocities are lower (0.1T, 0.3T at blue and red) than what is needed for minimal jitter at the lower velocities(0.3T, 0.4T at blue and red). Also, significantly lower powers are needed in the blue compared to red and the maximum modulation obtainable with the blue is higher than at red. Finally, the minimum overwrite jitter at blue is also less than at red.

REFERENCES

1. N. Yamada, ODS Digest, p 98, 1997.
2. Aparna Sheila, D.N.Lambeth, T.E. Schlesinger, SPIE **4090**, 116, 2000
3. S. Ohkubo, M. Okada, M. Murahata, T.Ide, T.Iwanaga, Jpn. J. Appl. Phys., **32**, 5230, '93.
4. Y. Kasami, Y. Kuroda, K. Seo, et al., Jpn. J. Appl. Phys. **39**, 756, Part 1, No. 2B, 2000